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Weights and dimensional properties of shrubs and small trees of the Great Lakes conifer forest

Peter J. Roussopoulos and Robert M. Loomis

North Central Forest Experiment Station
Forest Service, U.S. Department of Agriculture

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Presents equations for estimating biomass and woody size class distributions for shrubs and small trees (< 2.5 cm d.b.h.) of 17 northeastern Minnesota species. Relations between stem diameter at 15 cm above ground and plant height, crown length, and stem diameter at ground are also given.

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North Central Forest Experiment Station
Robert A. Hann, Director
Forest Service - U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108
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WEIGHTS AND DIMENSIONAL PROPERTIES OF SHRUBS AND SMALL TREES OF THE GREAT LAKES CONIFER FOREST

Peter J. Roussopoulos, *formerly Associate Forest Fuels Scientist, East Lansing, Michigan (currently with the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado)*
and **Robert M. Loomis,** *Fire Control Scientist, East Lansing, Michigan*

Biomass estimates are often used in determining primary productivity of ecosystems, quantifying energy pathways and nutrient cycles, anticipating product yields from harvest activities, evaluating wildlife habitats, and appraising forest flammability. Accordingly, biomass information needs and estimation methods have been discussed frequently in the literature of several disciplines. Specific information requirements vary substantially, though, depending on the context of the problem being considered.

One of the most information-demanding uses is the assessment of wildland fire behavior potential (Rothermel 1972), requiring quantitative estimates of available fuel weights by condition (living or dead) and by size category.

Studies reporting data suitable for fuel modeling in Great Lakes conifer forests (Rowe 1959) are rare, especially for the unmerchantable parts of a forest community such as small trees and shrubs (Ohmann *et al.* 1976, Crow 1977, Telfer 1969). Although these reports have some value for fuel evaluation, they fail to estimate component weights by dead or live categories or by size classes as desired for fire behavior prediction. A recent study by Brown (1976) devised estimating equations for 25 shrubs of the northern Rocky Mountains. Equations were presented to estimate foliage and stemwood with a table of percentages of stemwood within specific fuel size classes for species groups.

To appraise upland forest fuels and wildfire potential for the Boundary Waters Canoe Area in northeastern Minnesota, above ground biomass equations were developed for locally prominent shrubs and small trees. The resulting equations are presented herein, with primary emphasis on applications involving fuel modeling and fire behavior prediction.

METHODS AND ANALYSIS

Shrubs and small trees (<2.5 cm d.b.h.) were collected during July and August of 1976 on the Kawishiwi Ranger District of the Superior National Forest in northeastern Minnesota (47°50′N and 91°45′W). Stems were cut at groundline and were taken to the Kawishiwi Field Laboratory for processing. Seventeen different species were sampled, each represented by at least 20 collected stems. For each sample stem, the following sample measurements were recorded: stem diameter at ground level and at 15 cm above ground level to the nearest 0.25 cm (measurement of diameter at 15 cm above ground avoids the region of high stem taper normally found at groundline); plant height, and length (depth) of crown to the nearest 15 cm. Each plant was divided into components of foliage and woody parts. Dead and live woody parts were also separated. All woody parts[1] were further separated into size classes by diameter: 0 to 0.6 cm, 0.6 to 2.5 cm, and 2.5 to 7.6 cm. These size groups correspond to the 1-, 10-, and 100-hour timelag fuels described in the National Fire Danger Rating System by Deeming *et al.* (1972). Each component group was weighed to the nearest 0.1 gram and its moisture content determined by subsampling and ovendrying for 24 hours at 105 C. All fresh weights were converted to ovendry in this manner.

[1]Hereafter, "woody" refers to the woody parts of the plant; i.e., the composite of wood and bark.

To facilitate subsequent mathematical representation, measured dry weights of wood attributable to the three mutually exclusive size classes were arithmetically combined into the inclusive size classes: 0-0.6 cm, 0-2.5 cm, and 0-7.6 cm.

Regression analysis was used to relate component dry weights to stem diameter at 15 cm height. Analysis of variance and graphical analysis were used to compare regression equations for individual species and explore possibilities for grouping similar species.

Total plant weight, foliage weight, total wood weight (live and dead), and live wood weight, all in grams dry weight (Y), were regressed with stem diameter (X), measured in cm at a height of 15 cm, using the allometric model:

$$Y = aX^b \quad (1)$$

Regression coefficients were estimated using the logarithmic transformation of equation (1). The "a" coefficient was adjusted for bias inherent in this procedure (Baskerville 1972).

For each stem, the dry weights of all woody material less than 0.6 cm in diameter and all woody material less than 2.5 cm in diameter were divided by the overall weight for total wood and for live wood only. These ratios (Y) represent the proportional contribution of size classes 0 to 0.6 cm and 0 to 2.5 cm, inclusive, to the weight of the live and the total woody components. They were regressed against the stem diameter (X) at a height of 15 cm using the hyperbolic model:

$$Y = X/(a + bX) \quad (2)$$

The regressions were performed using the following linearized form:

$$X/Y = a + bX \quad (3)$$

In this form, the dependent variable (X/Y) is used only to evaluate the coefficients "a" and "b" for subsequent use in equation (2).

To help evaluate the bulk density and vertical distribution of understory fuels, linear regression equations were also developed for plant height and crown length on the stem diameter at 15 cm in height. These were statistically forced through the origin to produce a simple ratio estimator for plant height and crown length. Although this approach may be questionable for small plants (since all plants less than 15 cm tall are predicted to have zero height and crown length), the resulting errors are deemed negligible within the diameter range of principal interest. Even for smaller stems, the height and crown length measurement resolution (± 7.5 cm) tends to minimize the importance of potential underestimates.

RESULTS AND DISCUSSION

In all, 460 stems were collected and processed representing 14 deciduous species of trees and shrubs and three coniferous trees (table 1). For all species, the range of sampled stem diameters was 0.3 to 5.1 cm at 15 cm above ground. All species were represented over the bulk of this interval except *Diervilla lonicera, Lonicera canadensis,* and *Rosa acicularis.* These small shrubs rarely attain stem diameters outside the range sampled. Total above ground dry weight per stem ranged from 1 to 2,714 grams dry weight for all species.

Component Weights

Regression statistics were calculated for dry weights of all above ground components, foliage, total wood, and live wood (table 1). Examination of the coefficients of determination (r^2) shows reasonably good fits for all species except *Diervilla lonicera* and *Lonicera canadensis.* These low r^2 values may be partially due to the narrow range (0.2 cm for *Diervilla*) of sampled stem diameters compared to the measurement resolution (± 0.12 cm).

Meaningful species groupings, to facilitate aggregate modeling of forest communities for broad fuel appraisal, were illusive. No statistically defensible groups could be found that were applicable for all four dependent variables. The three species groups appearing in table 1 were derived through graphical comparisons of the regression equations. Though the F-test did not fully support these groups, differences among the individual "within-group" equations were generally not meaningful, from a practical standpoint, over the expected range of stem diameters. Extreme individual species estimates of "total" weight varied about 20 percent from the group estimate for the combined 11 species at a common 1.6-cm base diameter.

The regression equations agree quite well with those of Ohmann *et al.* (1976) except for *Corylus cornuta,* where their estimates show somewhat

Table 1.—*Sample size and regression coefficients*[1] *for estimating component dry-weights of shrubs and small trees (< 2.5 cm d.b.h.)*

Species	Stems collected	Range of stem diameters	Total				Foliage				All wood				Live wood			
			a	b	r^2	Sy·x	a	b	r^2	Sy·x	a	b	r^2	Sy·x	a	b	r^2	Sy·x
Abies balsamea	25	0.5-3.3	72.715	2.250	0.96	80	29.319	2.011	0.94	38	42.904	2.404	0.97	50	41.330	2.394	0.97	49
Acer rubrum	36	0.3-4.1	60.367	2.342	.94	278	13.082	1.840	.91	25	45.947	2.505	.93	274	45.085	2.480	.92	246
Acer spicatum	25	0.3-4.3	73.182	2.259	.95	141	17.305	1.696	.89	26	54.779	2.407	.95	122	52.384	2.417	.95	127
Alnus spp.	28	0.8-4.1	63.280	2.380	.93	164	14.725	1.828	.90	18	48.762	2.509	.90	164	48.077	2.484	.90	160
Amelanchier spp.	27	0.5-4.1	71.534	2.391	.93	174	10.478	1.988	.83	21	60.997	2.445	.94	160	58.333	2.458	.91	160
Betula papyrifera	23	1.3-3.6	76.316	2.279	.93	73	14.717	1.529	.66	17	62.830	2.378	.93	75	61.956	2.376	.92	77
Cornus rugosa	27	0.3-3.6	74.114	2.457	.96	124	17.131	2.093	.93	13	55.886	2.591	.96	136	54.629	2.551	.95	132
Corylus cornuta	36	0.3-2.5	62.819	2.420	.89	46	12.115	2.010	.81	8	50.154	2.523	.90	47	49.245	2.503	.90	44
Diervilla lonicera	21	0.3-0.5	14.211	1.217	.45	4	3.082	.613	.19	1	12.269	1.608	.53	3	9.276	1.445	.59	1
Lonicera canadensis	25	0.3-1.0	33.900	1.793	.68	5	5.319	1.275	.39	2	28.899	1.942	.67	4	28.017	2.020	.69	4
Picea spp.	25	0.5-3.3	65.757	2.287	.97	68	36.288	2.047	.95	42	28.670	2.566	.98	38	27.806	2.543	.97	34
Populus spp.	27	0.5-3.3	46.574	2.527	.96	52	10.828	2.052	.87	19	35.264	2.657	.97	41	34.906	2.655	.97	41
Prunus spp.	25	0.8-3.8	68.041	2.237	.90	155	12.382	2.024	.77	42	55.076	2.306	.87	152	54.235	2.253	.86	143
Rosa acicularis	23	0.3-1.3	83.240	2.837	.83	9	22.853	2.282	.79	3	63.140	3.224	.82	9	60.282	3.214	.83	8
Salix spp.	25	0.5-3.0	55.925	2.594	.96	113	12.280	2.120	.94	32	43.316	2.726	.95	96	42.495	2.721	.95	95
Sorbus americana	24	0.5-3.8	44.394	3.253	.95	350	8.083	2.601	.93	11	35.960	3.427	.95	407	35.585	3.425	.95	398
Thuja occidentalis	38	0.3-5.1	68.423	1.863	.94	86	35.288	1.442	.90	36	30.800	2.244	.94	62	30.632	2.232	.94	59
Abies balsamea & Picea spp.	50	0.5-3.3	69.167	2.267	.97	73	32.743	2.033	.94	48	35.691	2.480	.96	59	34.483	2.464	.96	52
Diervilla lonicera & Lonicera canadensis	46	0.3-1.0	25.879	1.636	.60	5	4.340	.944	.30	1	22.768	1.913	.60	4	20.190	1.898	.63	4
Eleven species[2]	303	0.3-4.1	62.134	2.460	.93	155	12.573	2.006	.86	24	48.944	2.577	.93	152	47.780	2.567	.92	146

[1]Regressions are of the form $Y = aX^b$ where Y is the component weight in grams, X is the stem diameter in centimeters measured 15 centimeters above ground, and a and b are regression coefficients from the table. Weights are expressed in grams of total above ground material (Total), foliage (Foliage), dead and live woody parts (All wood), and live woody parts only (Live wood) for 17 species or genera and 3 species combinations.

[2]*Acer rubrum, Acer spicatum, Alnus* spp., *Amelanchier* spp., *Betula papyrifera, Cornus rugosa, Populus* spp., *Corylus cornuta, Prunus* spp., *Salix* spp., *Sorbus americana.*

lower weights— especially at the larger stem diameters. We found this species similar to *Alnus* spp., *Amelanchier* spp., and *Salix* spp.—genera that Ohmann *et al.* combined also. Because their samples were collected in the same general location, and because they also used stem diameter measured at a height of 15 cm as the independent variable, close agreement is not surprising. Brown (1976) and Telfer (1969), on the other hand, used stem diameter at ground level.

To facilitate comparison with the results of these studies, the relation between the 15-cm stem diameter and basal stem diameter was examined. Scatter diagrams suggested that ground diameter could be predicted from the 15-cm diameter using simple linear regressions. The resulting coefficients were remarkably similar for all species (table 2). Telfer's (1969) weight predictions for woody plants in eastern Canada, after diameter adjustment, were also in close agreement. Brown's (1976) equations, on the other hand, yielded lower weight estimates for most species, perhaps partially due to the different environmental conditions of the northern Rocky Mountains. Both Brown and Telfer predicted greater weights for *Lonicera* spp. at larger diameters (Brown's weights were lower than Telfer's). Brown had the broadest diameter range for *Lonicera* (0.3 to 1.7 cm); Telfer's was similar to this study (0.1 to 0.7 cm).

Woody Size Classes

Examination of scatter diagrams revealed that the proportional contributions of the 0- to 0.6-cm and 0- to 2.5-cm (inclusive) size classes to total woody weight are discontinuous functions of stem diameter. They equal 1.0 at low stem diameters and fall quickly away from this value above some "critical stem diameter" near the upper size class limit. To ensure realistic size class predictions on both sides of this discontinuity, two measures were necessary. First, for each size class we found the diameter of the smallest stem that contained woody material in the next larger size class. Naturally, these values were close to the upper diameter limits—about 0.5 cm for the 0- to 0.6-cm class and 2.1 cm for the 0- to 2.5-cm class—and varied little among species. Stems with diameters below

Table 2.—*Regressions through origin (y = bx) for height and crown length, and linear regressions (y = a + bx) for basal stem diameter versus stem diameter (cm) at 15 cm above ground level*

Species	Height (meters)			Crown length (meters)			Basal diameter (cm)				
	b	Sy·x	n	b	Sy·x	n	a	b	r^2	Sy·x	n
Abies balsamea	0.7094	0.2902	25	0.6455	0.2876	25	0.0684	1.1302	0.9216	0.2929	25
Acer rubrum	1.3761	.5851	33	.9522	.6927	33	.0003	1.1675	.9649	.2039	36
Acer spicatum	1.2100	.4989	22	.7443	.4093	22	.1645	1.0485	.9499	.2488	25
Alnus spp.	1.1289	.8339	6	.5331	.9089	6	.1409	1.0225	.9592	.1695	28
Amelanchier spp.	1.3176	.3496	17	.8061	.3114	17	.0142	1.1037	.9815	.1569	27
Betula papyrifera	1.5720	.5564	21	.9837	.7265	21	.1713	1.0452	.9376	.1968	23
Cornus rugosa	1.1728	.6782	29	.6860	.4204	27	.0243	1.0828	.9714	.1505	27
Corylus cornuta	1.5314	.3192	36	.9510	.3085	36	.1894	.9226	.9476	.1214	36
Diervilla lonicera	1.3268	.1389	21	.8179	.1520	21	.1062	.8818	.5216	.1126	21
Lonicera canadensis	1.2184	.2402	25	.7488	.1876	25	.0809	.9780	.7346	.1188	25
Picea spp.	.5772	.1769	25	.5050	.1389	25	.0715	1.1241	.9711	.1858	25
Populus spp.	1.2515	.5219	27	.8136	.6473	27	.1294	1.0517	.9643	.1752	27
Prunus spp.	1.2183	.5750	19	.7943	.3435	19	.1151	1.0676	.9417	.2094	25
Rosa acicularis	1.4505	.1967	23	.8661	.1609	23	.0338	1.0412	.8412	.1092	23
Salix spp.	1.2747	.5282	17	.7497	.4044	17	.0502	1.1730	.9810	.1543	25
Sorbus americana	1.5018	.4470	24	.9532	.4532	24	.0263	1.1373	.9735	.1370	24
Thuja occidentalis	.6290	.2256	38	.6063	.2124	38	.1853	1.0906	.9556	.2925	38
All coniferous	.6350	.2518	88	.5884	.2441	88	.1293	1.1058	.9514	1.4084	88
All deciduous	1.3293	.5156	318	.8342	.4923	318	.0434	1.1072	.9670	1.0127	372

these values were deleted from the respective size class regressions. This eliminated samples from the "flat" section of the curve where the proportional size class contribution is 1.0 and allowed separate mathematical representation of the "flat" and "falling" curve sections. Second, the critical stem diameter—the point separating the two sections—was defined from the coefficients of each hyperbolic regression as a /(1−b). The regression equation applies only to stem diameters above this value, which results in the following expression for the fractional contribution of each size class (Y) in terms of stem diameter (X):

$$Y = \begin{cases} 1.0, \text{ for } 0 < X < \dfrac{a}{(1-b)} \text{ ("flat" section)} \\ \dfrac{X}{(a + bX)}, \text{ for } \dfrac{a}{(1-b)} \leq X \text{ ("falling" section)} \end{cases} \quad (4)$$

Regression coefficients were calculated for use with equation (4), both for all wood and for live wood only (table 3). For the < 0.6 cm size class regressions, *Diervilla lonicera* was the only species that had no samples with stem diameters more than 0.5 cm. Regressions were performed for all other species. *Diervilla, Corylus cornuta, Lonicera canadensis, Rosa acicularis,* and *Sorbus americana* were exempted from the 0.0 to 2.5 cm size class regression analysis because each had less than five sampled stems that were 2.1 cm or more in diameter. Good fits were obtained for most of the remaining species with this model. Regressions were also run for the three species groups used earlier. Again, analysis indicated the combinations to be reasonable and practical, though statistically not fully justifiable.

Actual weight estimates for each size class can be obtained by multiplying the appropriate fractional weight contribution estimate (equation (4), table 3), times the corresponding predicted wood weight (equation (1), table 1). Weights of the 0.6- to 2.5-cm and > 2.5-cm size classes, as well as dead wood weights may be found by subtraction.

At small stem diameters, below about 0.5 cm, the entire woody component is within the 0- to 0.6-cm size class (fig. 1). As stem diameter increases above this point, the fractional contribution of this class drops quickly to an asymptote at 0.14 (for the grouped 11 deciduous species), while the 0.6- to 2.5-cm class becomes prominent. At roughly 2.3 cm, material greater than 2.5 cm appears and the middle size class begins to fall

Table 3.— *Regression statistics for estimating fractional weight contributions of woody components by size class and condition (live or dead) for 17 species and 3 species combinations of northern Minnesota shrubs and small trees. The regression model is $X/Y = a + bX$, where independent variable X is stem diameter (cm) measured 15 cm above ground level and Y is the fraction by weight attributed to each indicated size class.*

Species	All woody parts ≤0.6 cm divided by all woody parts					Live woody parts ≤0.6 cm divided by live woody parts					All woody parts ≤2.5 cm divided by all woody parts					Live woody parts ≤2.5 cm divided by live woody parts				
	a	b	r^2	Sy·x	n	a	b	r^2	Sy·x	n	a	b	r^2	Sy·x	n	a	b	r^2	Sy·x	n
Abies balsamea	−0.8141	2.3989	0.924	0.6129	25	−1.0298	2.6303	0.911	0.7324	25	−4.2677	2.8728	0.940	0.3290	9	−4.7586	3.0867	0.928	0.3887	9
Acer rubrum	−6.2520	10.3120	.718	5.9481	33	−7.4744	11.5724	.734	6.5710	33	−6.0540	3.5985	.805	1.1121	8	−6.2718	3.7192	.687	1.3304	8
Acer spicatum	−4.7664	7.6075	.925	2.1277	23	−5.3703	8.5717	.913	2.6055	23	−8.6441	4.1621	.939	.7271	6	−8.8463	4.2436	.940	.7397	6
Alnus spp.	−4.2928	6.9640	.854	2.3184	28	−5.0621	7.7270	.821	2.9061	28	−3.8505	2.8249	.946	.5092	6	−3.9024	2.8765	.940	.5463	6
Amelanchier spp.	−4.0400	6.8436	.918	2.1167	27	−4.4118	7.2891	.905	2.4477	27	−6.4998	4.0315	.911	.7414	6	−7.0820	4.2563	.906	.8053	6
Betula papyrifera	−5.8830	7.7092	.915	1.7199	23	−7.1140	8.5998	.898	2.1135	23	−6.0057	3.5414	.973	.2942	10	−6.4097	3.7084	.972	.3138	10
Cornus rugosa	−2.6090	5.6040	.752	2.1095	24	−3.2924	6.4142	.788	2.2932	24	−.4652	1.1927	.978	.1039	7	−.4892	1.2027	.976	.1092	7
Corylus cornuta	−2.0501	4.6178	.896	.8202	33	−2.5036	5.2050	.904	.8849	33	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Diervilla lonicera	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Lonicera canadensis	−.8217	2.6503	.939	.1054	15	−.8217	2.6503	.939	.1054	15	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Picea spp.	−.7873	2.5976	.964	.4800	25	−.9063	2.8078	.952	.6046	25	−4.0003	2.7137	.922	.3528	9	−4.2958	2.8364	.938	.3236	9
Populus spp.	−4.8321	8.2591	.841	3.1064	27	−4.5801	8.3773	.829	3.2937	27	−6.3969	3.1764	.910	.5263	9	−6.4176	3.7228	.911	.5235	9
Prunus spp.	−2.0843	5.1685	.721	1.6514	24	−2.4157	5.8313	.694	2.1243	24	−4.7809	3.1011	.984	.6872	5	−4.7884	3.1078	.987	.6857	5
Rosa acicularis	−1.1971	3.3862	.911	.2203	17	−1.1971	3.3862	.911	.2203	17	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Salix spp.	−4.1190	7.4681	.760	4.4845	23	−4.1282	7.7257	.792	4.2844	23	−6.0504	3.5769	.760	1.1493	9	−6.1529	3.6205	.772	1.1484	9
Sorbus americana	−10.0310	15.1988	.932	2.9887	24	−9.9149	15.4869	.929	3.1181	24	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Thuja occidentalis	−4.8576	5.8264	.843	3.0684	36	−6.3768	6.9339	.797	4.2709	36	−8.3000	4.3000	.940	1.1477	13	−9.4581	4.7387	.935	1.3232	13
Abies balsamea & *Picea* spp.	−.8239	2.5127	.939	.5789	50	−.9923	2.7343	.926	.6987	50	−4.0207	2.7498	.926	.3331	18	−4.3792	2.9042	.924	.3590	18
Diervilla lonicera & *Lonicera canadensis*	−.8342	2.6645	.943	.0785	26	−.8359	2.6636	.944	.0782	26	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Eleven species	−4.0271	7.3193	.691	4.1284	296	−4.4322	7.9182	.703	4.3433	296	−5.0517	3.1742	.656	1.1939	72	−5.1878	3.2378	.650	1.2344	72

[1]Range of diameters insufficient to perform regression.

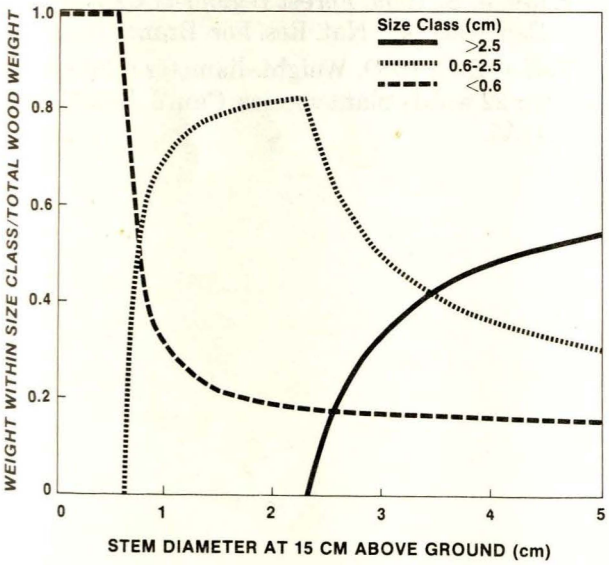

Figure 1.—*Fractional size class composition (by weight) of total stem and branchwood component versus stem diameter for a group of eleven species.*

toward its asymptote at 0.18. Once established, the largest class rises throughout the range of sampled stem diameters.

Also of interest for flammability appraisal is the "dead-to-live" ratio of stemwood. This may be found either by size class or for the entire stem by subtracting the appropriate "live woody parts" estimate from the corresponding "all woody parts" estimate, and dividing the difference by the estimate for the live. Dead-to-live ratios are often more easily interpreted in terms of shrub flammability than are actual component weights.

Plant Height and Crown Length

Besides the quantity and size distribution of fuel materials, spatial distribution or fuel arrangement also influences flammability. Knowledge of total heights and crown lengths of understory vegetation can be helpful in modeling forest fuels for predicting fire behavior. Equations were developed to predict these dimensions using 15 cm stem diameter as the predictor variable. Regression analysis using a forced 0-intercept was used (table 2). To preserve the noteworthy differences in slope

coefficients for coniferous versus deciduous species, only two grouped regressions were performed. Plant heights for the conifers were roughly half those of deciduous plants with the same stem diameter. The crown length ratios for coniferous samples (crown length/total height) are characteristically 1.5 times those of deciduous species. These statistical observations are confirmed by physical experience and seem to justify the chosen species combinations.

SUMMARY

Using regression equations presented in this paper, one may estimate the quantity and vertical distribution of understory fuels by component, live or dead, and wood size categories from inventories of easily measured plant dimensions. If only plant heights or only stem diameters at ground level are known, the measurements can be converted to stem diameter at 15 cm, the predictor variable for component weights and size class proportions. The estimating equations can be used with the most confidence within the diameter ranges sampled for individual species and do not apply to trees larger than 2.5 cm d.b.h.

LITERATURE CITED

Baskerville, G. L. 1972. Use of logarithmic regressions in the estimation of plant biomass. Can. J. For. Res. 2:49-53.

Brown, J. K. 1976. Estimating shrub biomass from basal stem diameters. Can. J. For. Res. 6:153-158.

Crow, Thomas R. 1977. Biomass and production regressions for trees and woody shrubs common to the Enterprise Forest. *In* The Enterprise, Wisconsin, Radiation Forest— Radioecological Studies. J. Zavitkovski, ed. p. 63-67. Tech. Inf. Cent., Energy Res. and Dev. Admin. TID-26113-P2.

Deeming, J. E., J. W. Lancaster, M. A. Fosberg, R. W. Furman, and M. J. Schroeder. 1972. The National Fire-Danger Rating System. U.S. Dep. Agric. For. Serv., Res. Pap. RM-84, 165 p. U.S. Dep. Agric. For. Serv., Rocky Mt. For. and Range Exp. Stn., Fort Collins, CO.

Ohmann, Lewis F., David F. Grigal, and Robert B. Brander. 1976. Biomass estimation for five shrubs from northeastern Minnesota. U.S. Dep. Agric. For. Serv., Res. Pap. NC-133, 11 p. U.S. Dep. Agric. For. Serv., North Cent. For. Exp. Stn., St. Paul, MN.

Rothermel, R. C. 1972. A mathematical model for predicting fire spread in wildland fuels. U.S. Dep. Agric. For. Serv., Res. Pap. INT-115, 40 p. U.S. Dep. Agric. For. Serv., Intermountain For. and Range Exp. Stn., Ogden, UT.

Rowe, J. S. 1959. Forest regions of Canada. Can. Dep. Natl. Aff. Nat. Res. For. Branch Bull. 123.

Telfer, E. S. 1969. Weight-diameter relationships for 22 woody plant species. Can. J. Bot. 47:1851-1855.

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